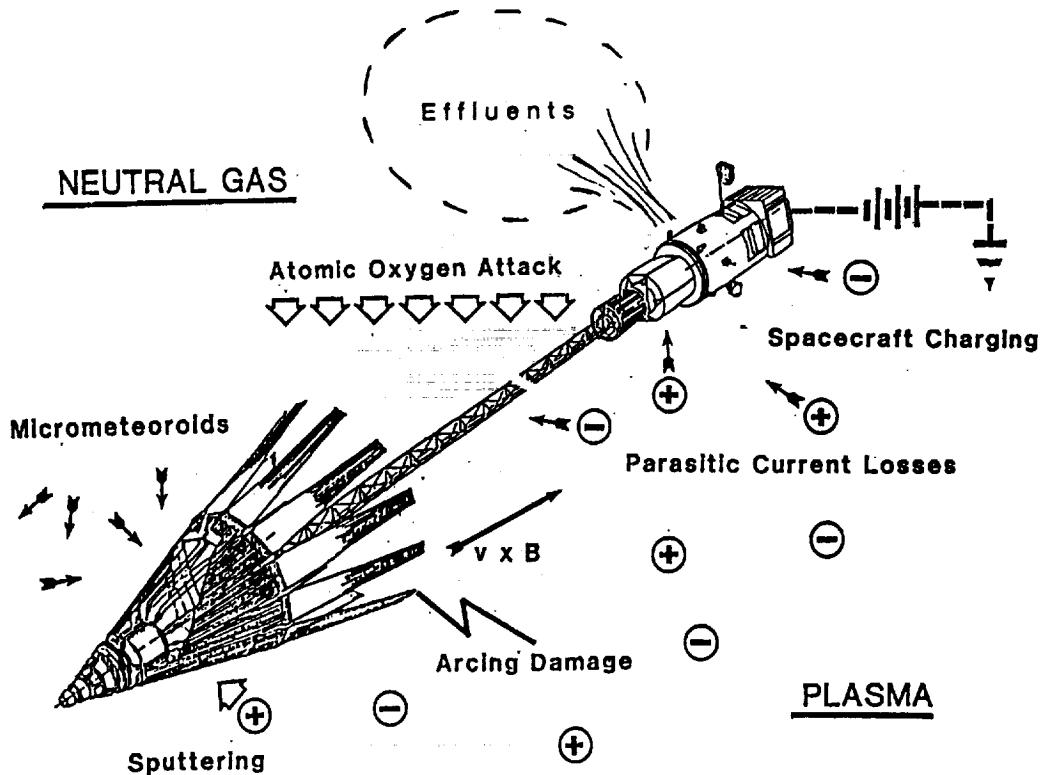


SPACE ENVIRONMENTAL INTERACTIONS FOR THE SPACE EXPLORATION INITIATIVE

Dale C. Ferguson
 National Aeronautics and Space Administration
 Lewis Research Center
 Cleveland, Ohio 44135

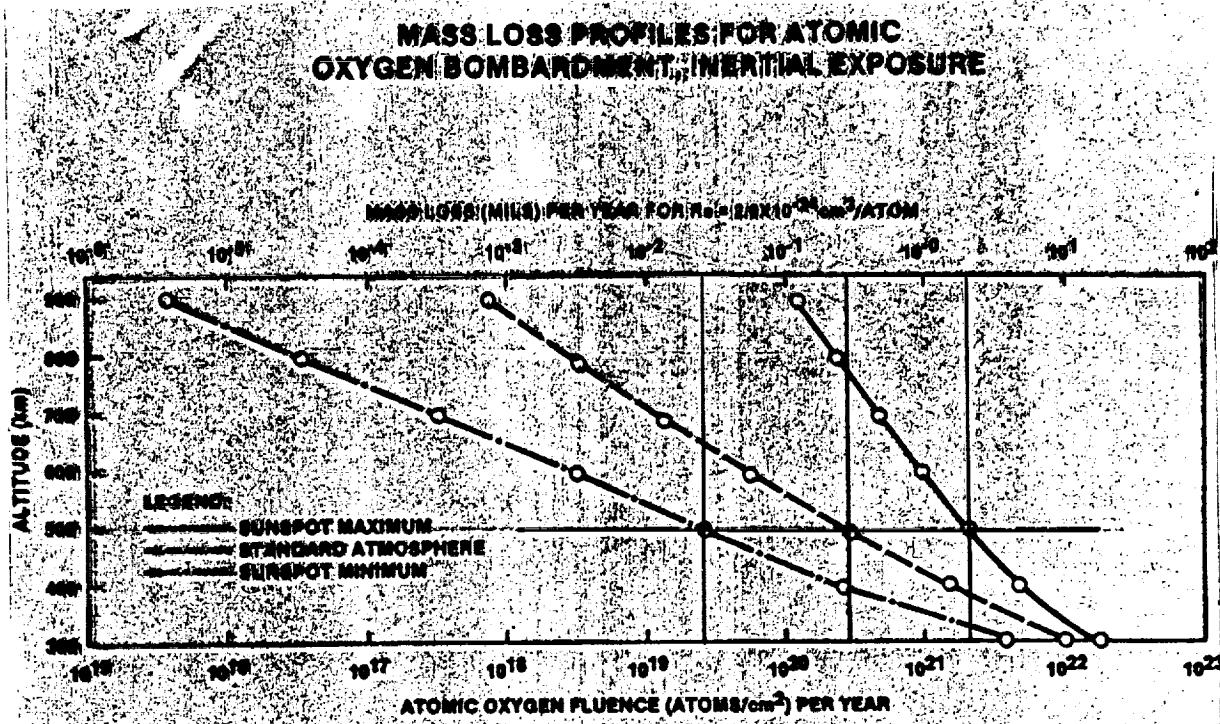
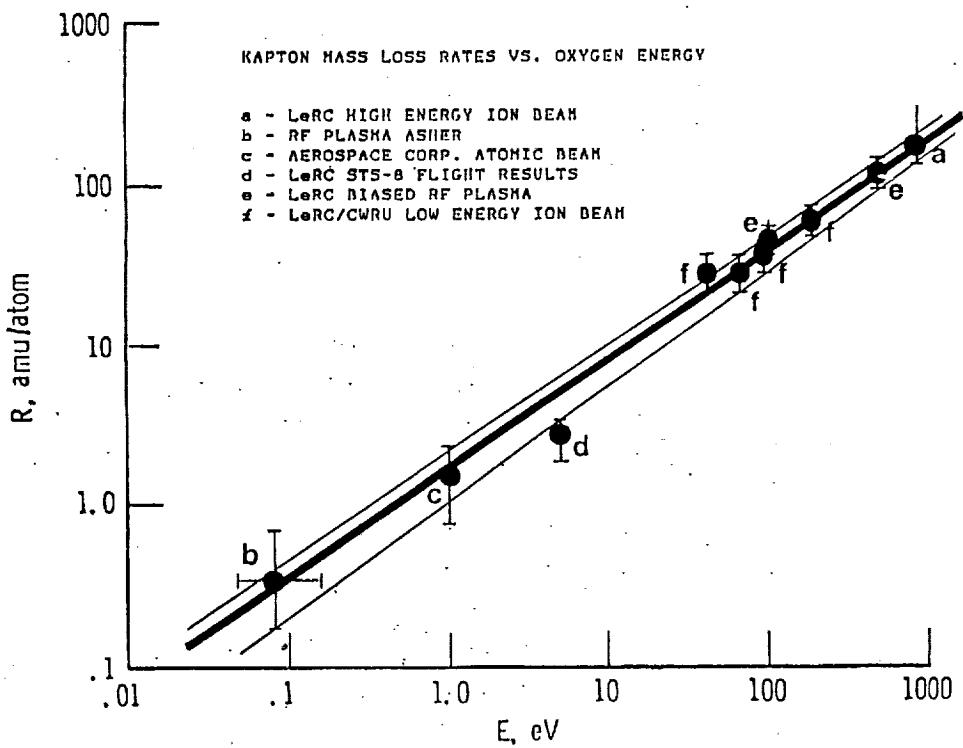
SPACECRAFT ENVIRONMENTAL EFFECTS



Space Environmental Interactions

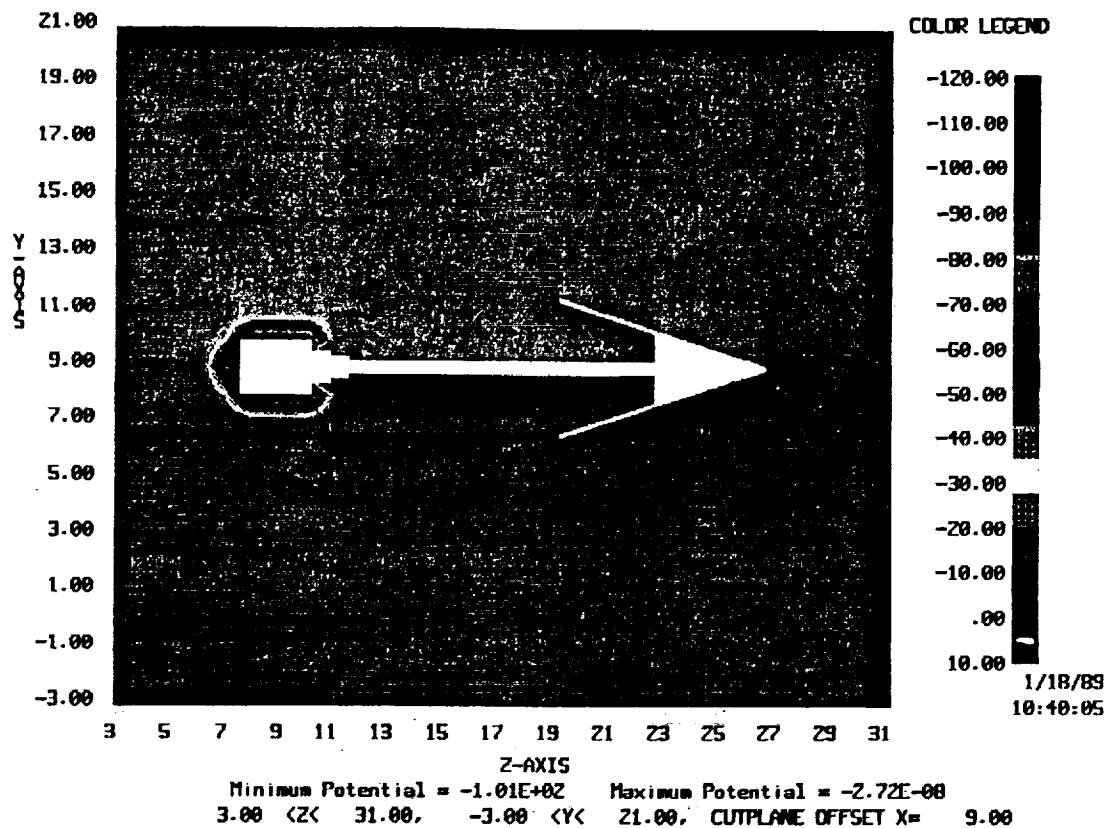
Atomic Oxygen Attack

- LOW PLANETARY ORBITS ONLY
 - Material Specific
 - Preferentially in Ram
 - Low Mars Orbit Also Contains AO
 - For Some Materials, Synergy w/ UV
 - Ionized AO Also Reactive.
- CHANGES MATERIAL SURFACE PROPERTIES
 - Optical and Thermal Properties
 - Surface Conductivities
 - Strength of Exposed Fibers



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Load Biased to 100V Neg. w.r.t. Body



Space Environmental Interactions

Arcing and Discharges

- GEOSYNCHRONOUS ENVIRONMENT
 - Differential Charging in Geo Substorms
 - Solar Flares in Interplanetary Space
- LOW PLANETARY ORBITAL ENVIRONMENTS
 - Arcing To or Thru Ionized Plasma
 - Dielectric Breakdown of Anodized Surfaces
 - Arcing at Conductor-Insulator Junctions
- PASCHEN BREAKDOWN - PLANETARY SURFACE
 - Martian Atm Pressure Ideal for Discharges
 - Lunar Camps Create Local Atmospheres

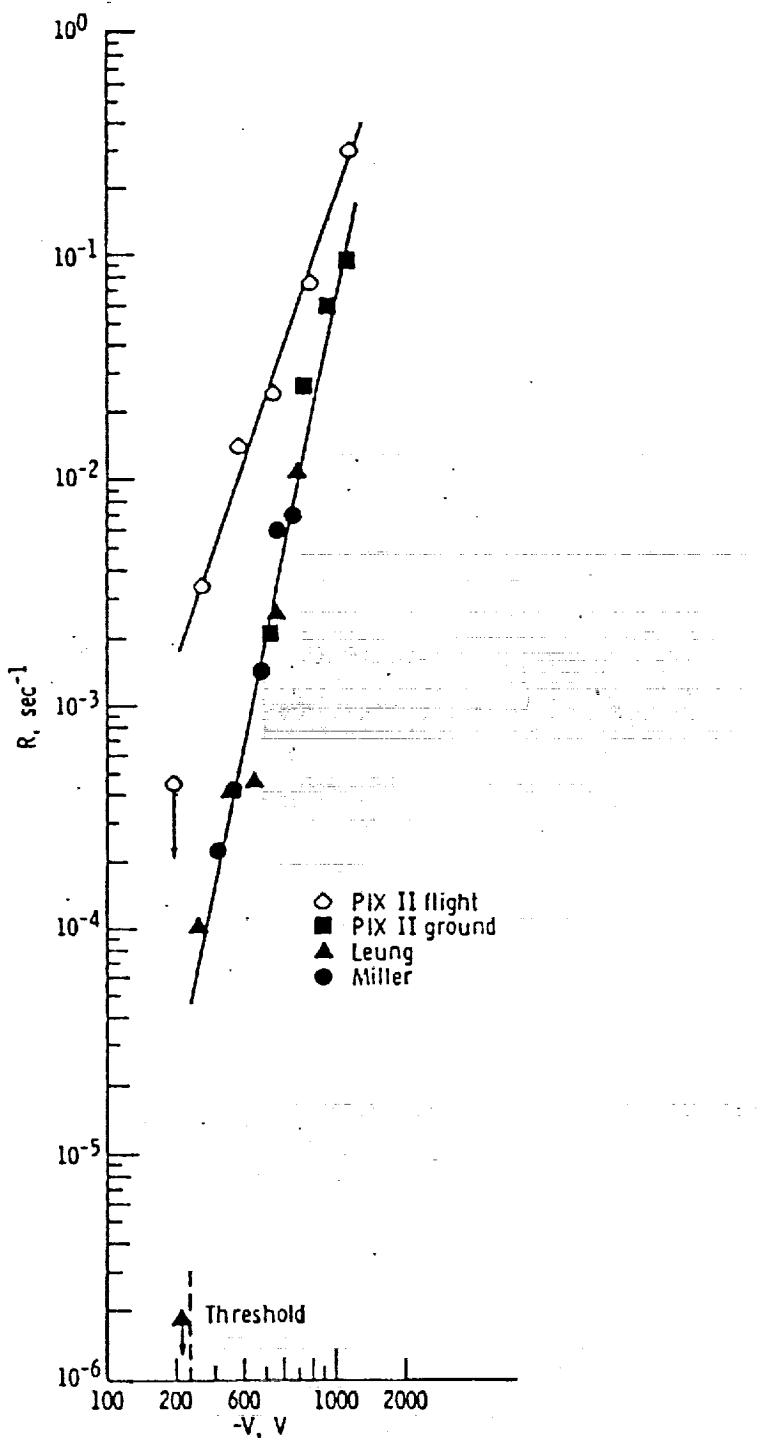


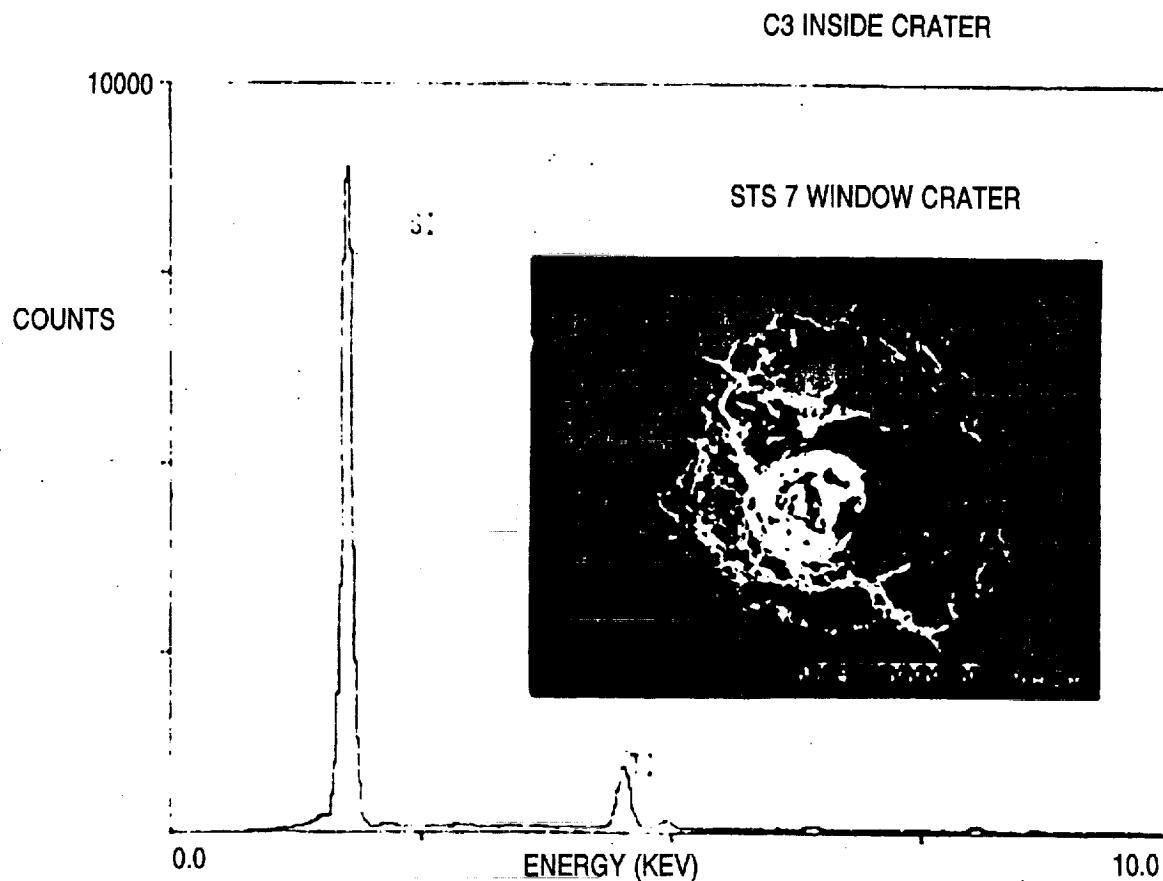
Figure 7. - Arc rate versus voltage for standard interconnect cells. Normalized to LEO ram conditions (see text).

Copyright © AIAA 1986 - Used with permission. Ferguson, D.C., The voltage threshold for arcing for solar cells in LEO-flight and ground test results, AIAA paper 86-0362, 1986.

Space Environmental Interactions

Micrometeoroids and Debris

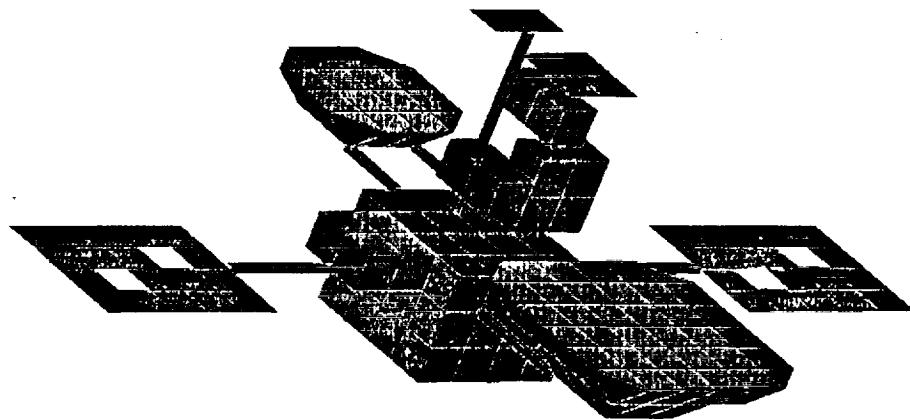
- SURFACE DAMAGE
 - Pinholes in Insulators
 - Change of Thermal Properties
 - Sites for Arcing, Sputtering
 - Possible Site of Kapton Pyrolysis
- NEED FOR REDUNDANCY OR HEALING
 - Fluid Lines and Heat Pipes
- LOCAL PLASMA CREATED AT SITE
 - May Produce Prompt Arcing
 - Arcs Enlarge Damaged Area
- DEBRIS PROBLEM IN PLANETARY ORBITS



Space Environmental Interactions

State-of-the-Art Computer Tools

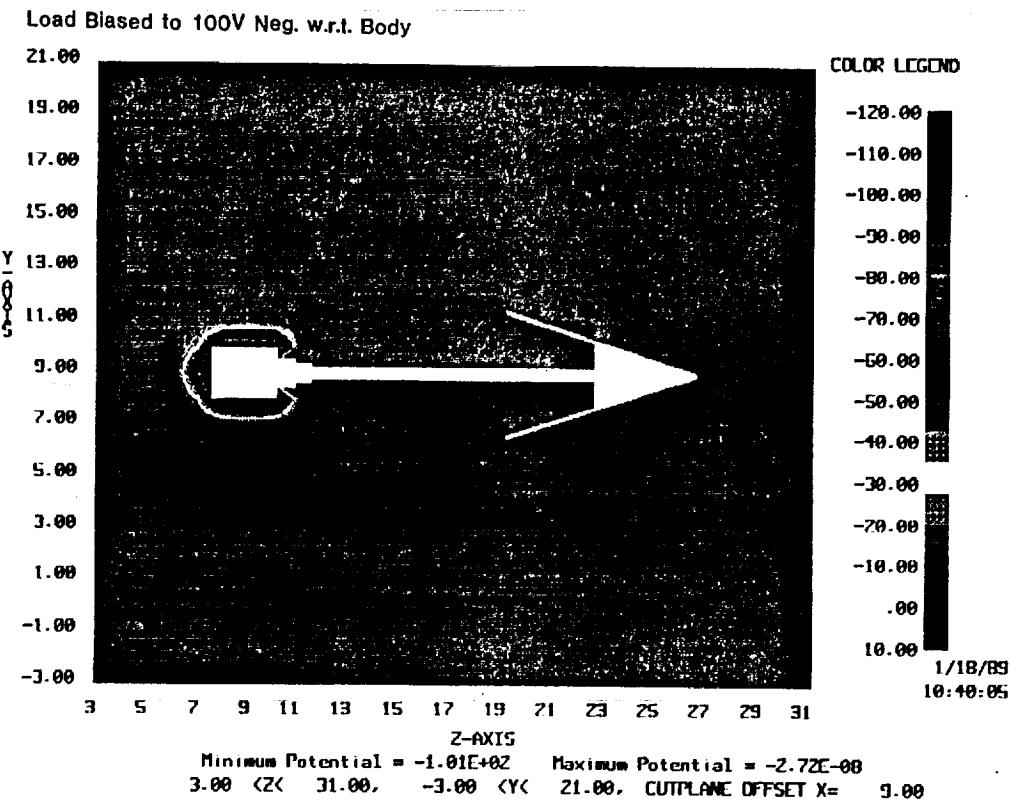
- S-CUBED DIV. OF MAXWELL LABORATORIES
- NASCAP (3-D, Particle Tracking)
 - Calculates Charging in GEO
 - Obtainable thru COSMIC
 - Mature Code, Industry Standard
- NASCAP/LEO (3-D, Particle Tracking)
 - Calculates Charging, Currents in LEO
 - Release thru COSMIC This Year
 - Under Final Testing
- EPSAT, EWB (1-D, Systems Tools)
 - Evaluate Multiple Interactions
 - Quick, Approximate
 - Under Beta Testing
 - May Be Ideal Starting Point for SEI



NASCAP model of NASA's
Advanced Communications Technology Satellite.

Figure 6

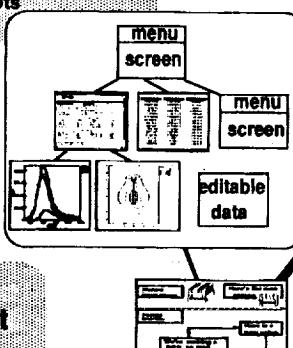
SP-100 Floating Potential



**EPSAT's Architecture Combines
A Powerful Display With
Changeable & Expandable Modeling Capabilities**

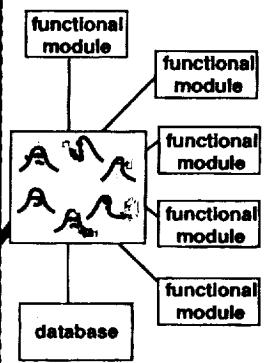
Flexible Display Module

- same commands for all functions
- data entry screens
- tables
- line graphs
- contour plots



Non-Procedural Process Controller

- does only the calculations necessary
for the desired result



Workstation Independent

- UNIX
- Fortran & C
- Sun 3, 4 Sparc
- Compaq
- Celarity

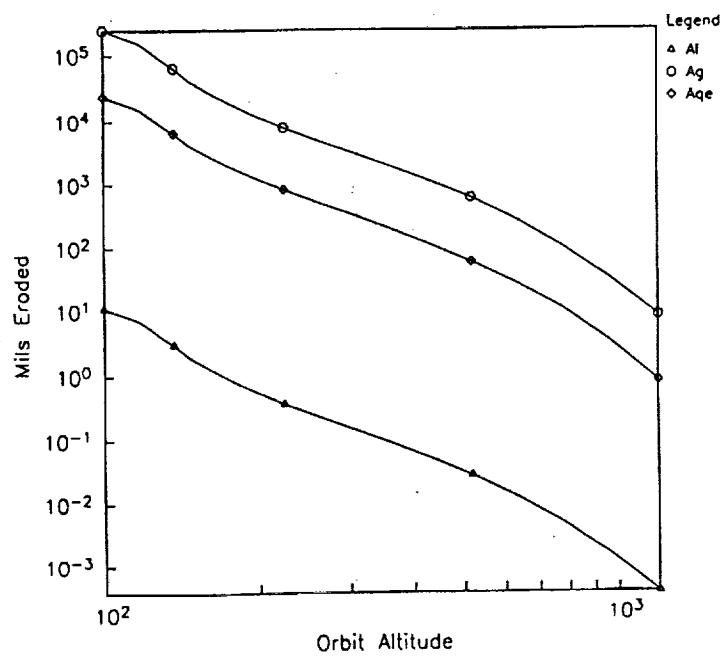
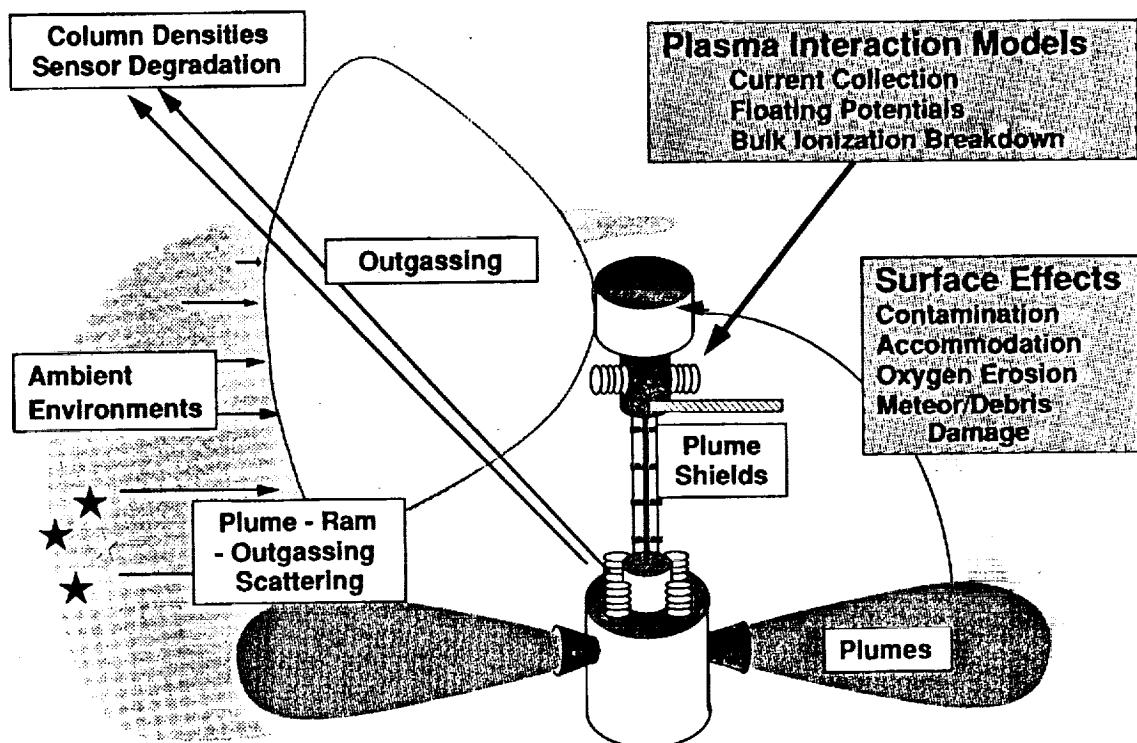
Object Oriented
message passing between modules

Software "Expansion Slots"
plug in new or
additional power
system models

Designed For Change

- editable screens
- text based data item dictionary
- coding standards
- all source government owned

EPSAT Power System Models



Total atomic oxygen erosion during a 10-year mission life for three conductive coatings as a function of altitude for 60° inclination circular orbits.

KAPTON 41 HOURS EXPOSURE TO ATOMIC OXYGEN ON STS-8

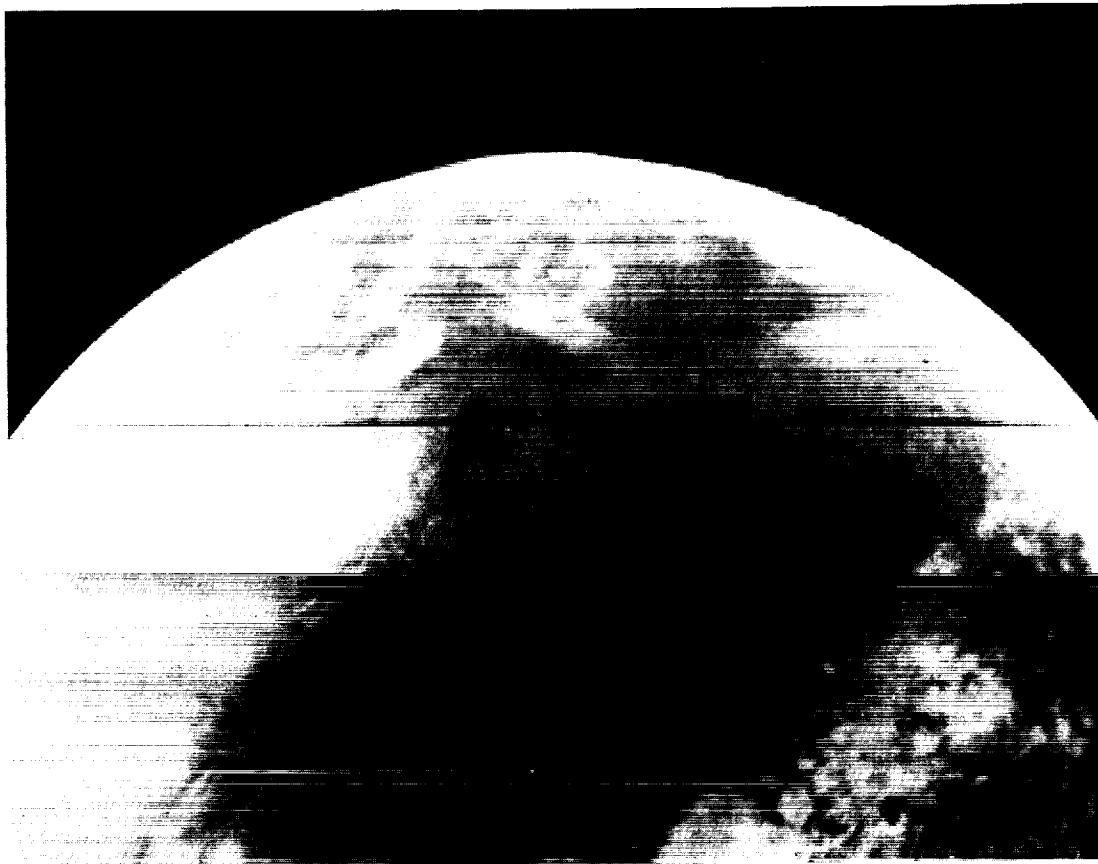


STS-8 FLIGHT SAMPLES

LeRC PRELIMINARY MASS LOSS MEASUREMENTS

(Corrected for mass change of control
due to moisture, etc.)

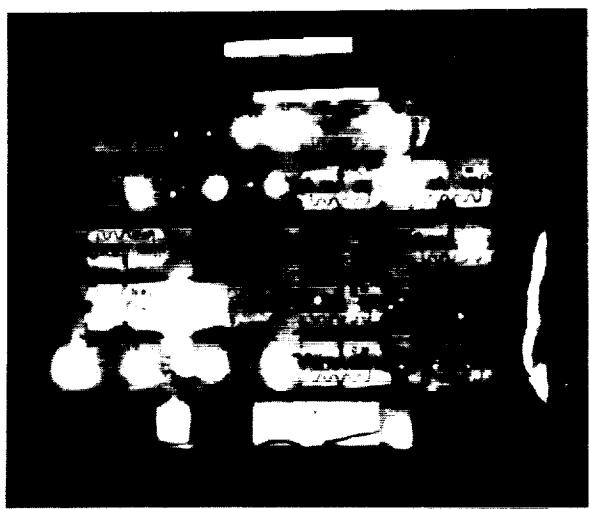
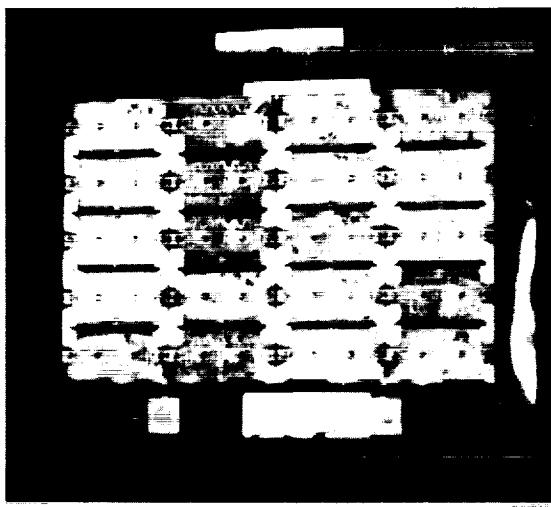
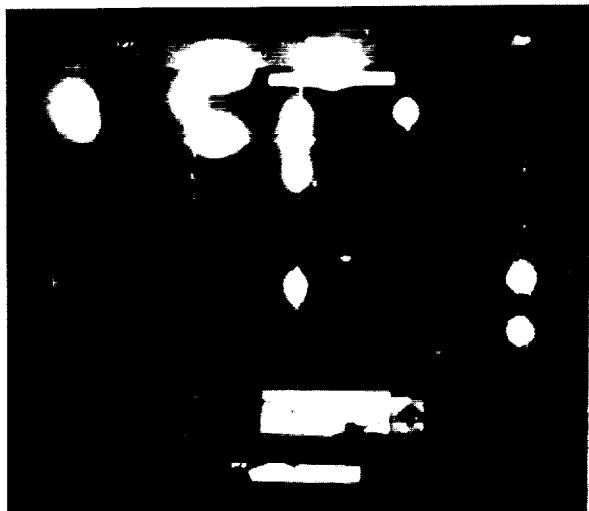
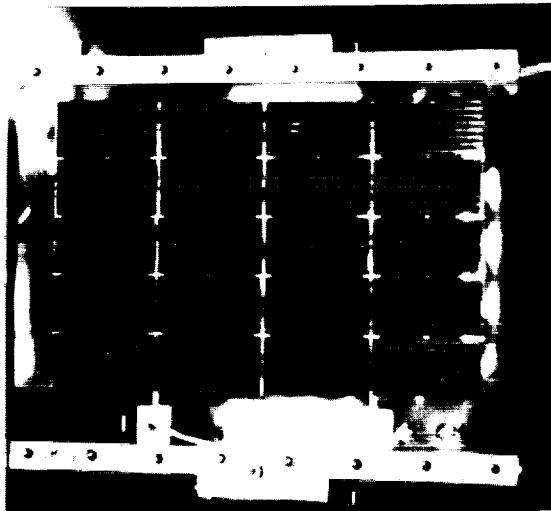
SAMPLE #	DESCRIPTION	MASS CHANGE (g)	(Assumes 3.87×10^{20} atoms/cm ²)		COMMENT
			DETERMINATION	ERROR	
1	5 mil Kapton, Al backed	-0.0050200 99	-3.88 x 10 ⁻²⁴ 01		
2	5 mil Teflon, Al backed	-0.0000820 91	-6.34 x 10 ⁻²⁶ 01		Low loss rate
3	5 mil Mylar, Al backed	-0.0056091 118	-4.34 x 10 ⁻²⁴ 01		HIGHEST MEASURED
4	MgF ₂ anti-reflection on glass	-0.0000204 259	-1.58 x 10 ⁻²⁶ 2.01		No sig. change
5	ITO on glass	-0.0000196 359	-1.46 x 10 ⁻²⁶ 2.78		No sig. change
6	96% SiO ₂ + 4% PTFE on 5 mil Kapton	-0.0000103 52	-7.98 x 10 ⁻²⁷ 4.04		Very low loss rate
7	Al ₂ O ₃ on 5 mil Kapton	-0.0005674 52	-4.40 x 10 ⁻²⁸ 04		LOWEST MEASURED
8	SiO ₂ on 5 mil Kapton	-0.0000058 52	-4.50 x 10 ⁻²⁷ 4.04		No sig. change
9	TiO ₂ on quartz	+0.00000437 147	+3.38 x 10 ⁻²⁶ 1.14		Low gain rate
10	Mo on sapphire	+0.0000760 235	+5.88 x 10 ⁻²⁶ 1.81		Low gain rate
11	Copper on sapphire	+0.0000764 767	+5.91 x 10 ⁻²⁶ 5.93		No sig. change
12	Chromium on Kapton, Al backed	-0.0000492 147	-3.81 x 10 ⁻²⁶ 1.14		Low loss rate



Space Environmental Interactions

Current Collection and Snapover

- ELECTRON COLLECTION AND SNAPOVER
 - Snapover at Potentials $> +100$ V
 - Insulators Act as Electron Conductors
 - Large Power Drains
- ION COLLECTION AND SPUTTERING
 - Ions Focused Onto Insulation Defects
 - Sputtering at Potentials < -100 V
- FLOATING POTENTIALS
 - Ion and Electron Currents Must Balance
 - Ease of Electron Collection Makes Systems Float Negative
- POWER SYSTEM GROUND IMPORTANT
 - Grounds on Moon, Mars Difficult?



ARCING ON SOLAR CELL ARRAY SAMPLES

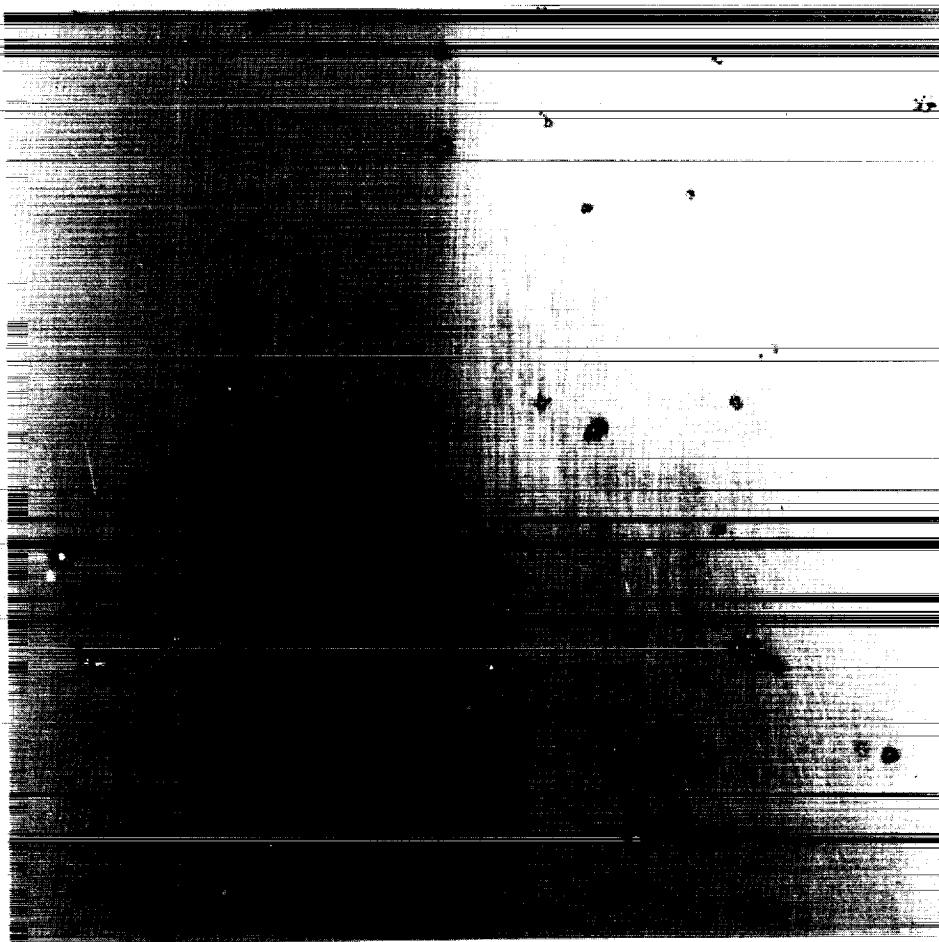
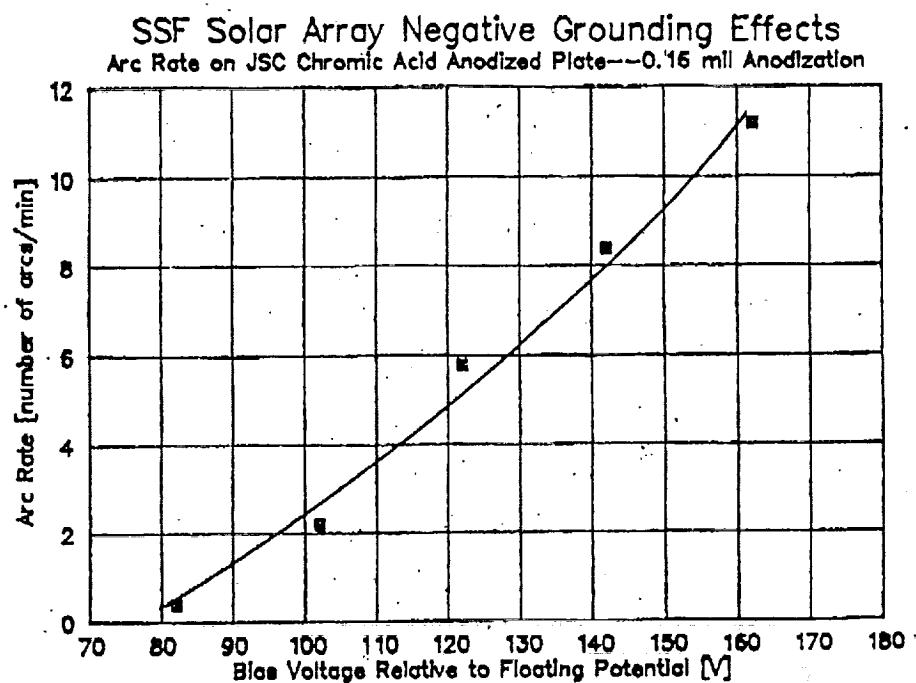
2x4 cm WRAPAROUND CELLS ON KAPTON

-1 kV BIASED ARRAY CIRCUIT

10^5 cm^{-3} N PLASMA (25 eV IONS, 3 eV e^-)

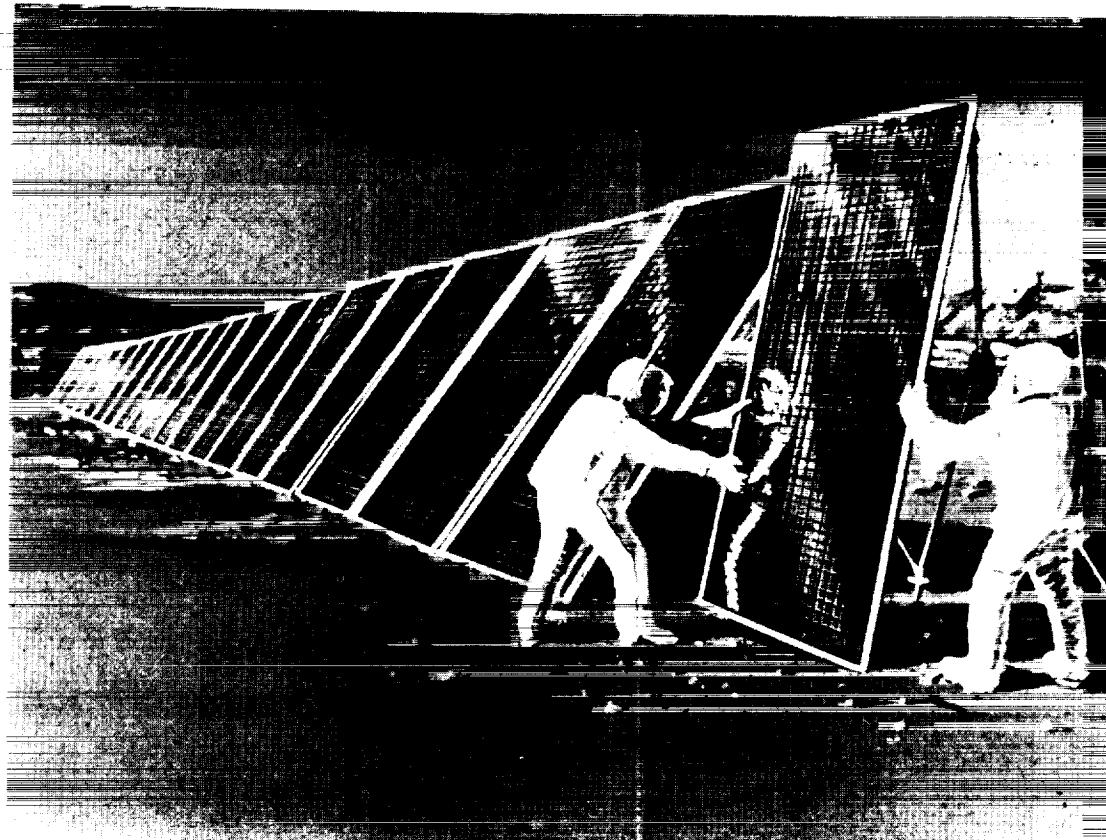
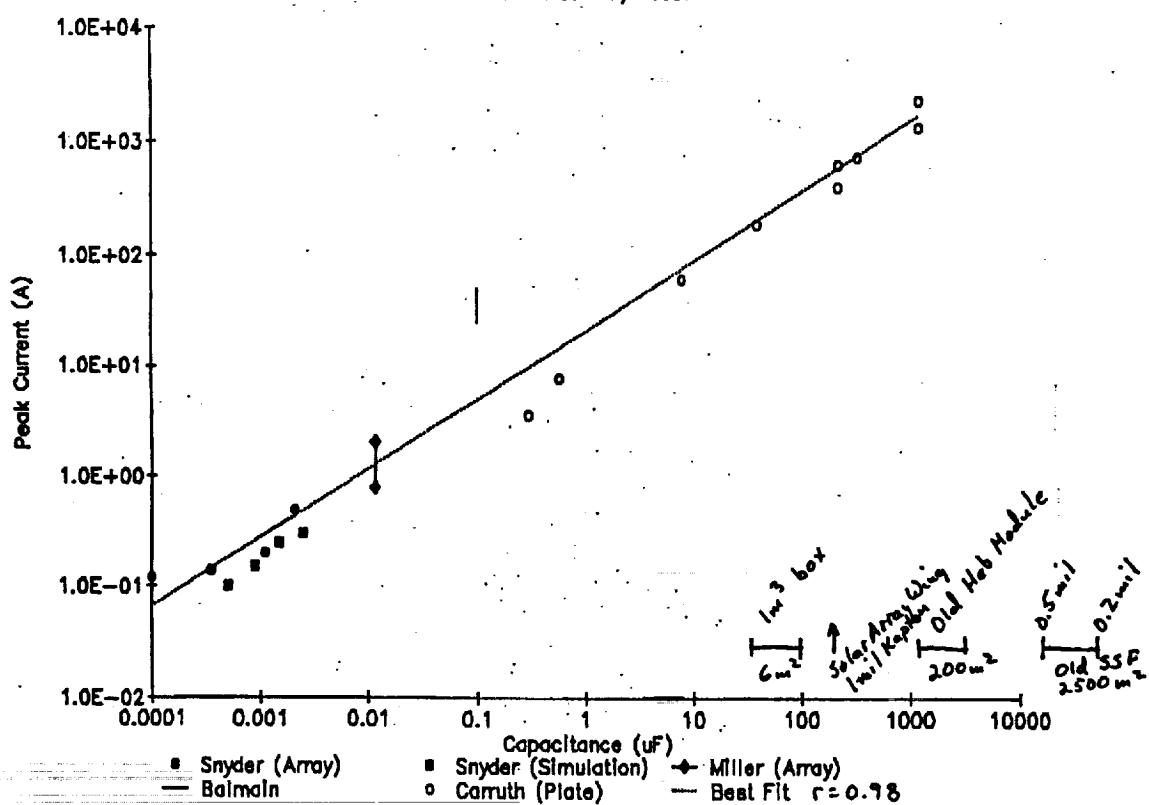
**NASA/LEWIS RESEARCH CENTER
ENVIRONMENTAL INTERACTIONS PROGRAM**

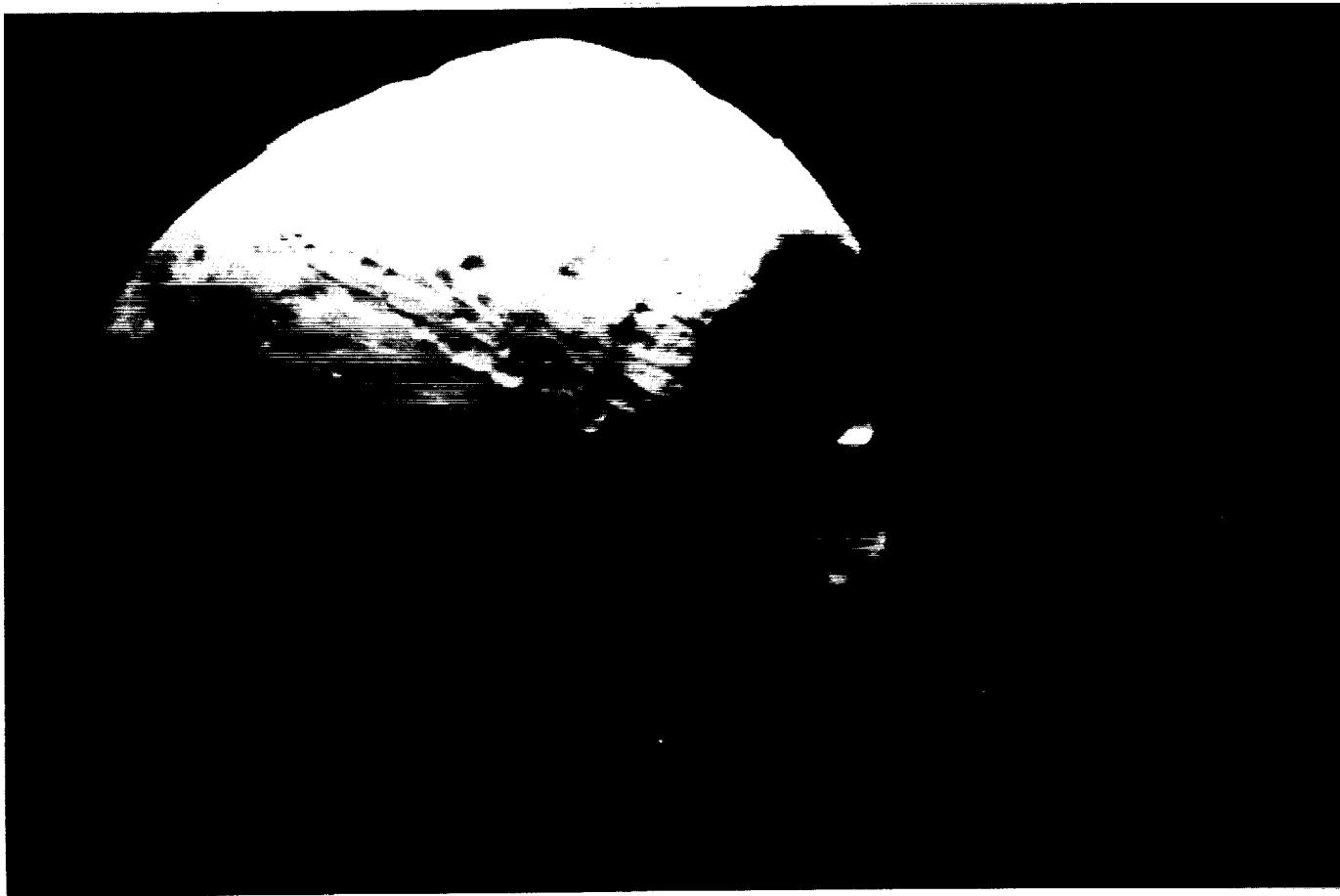
DIELECTRIC BREAKDOWN OF ANODIZED SURFACES IN A PLASMA



Peak Currents of Plasma Arcs

Best Fit Power: 0.62 ± 0.03

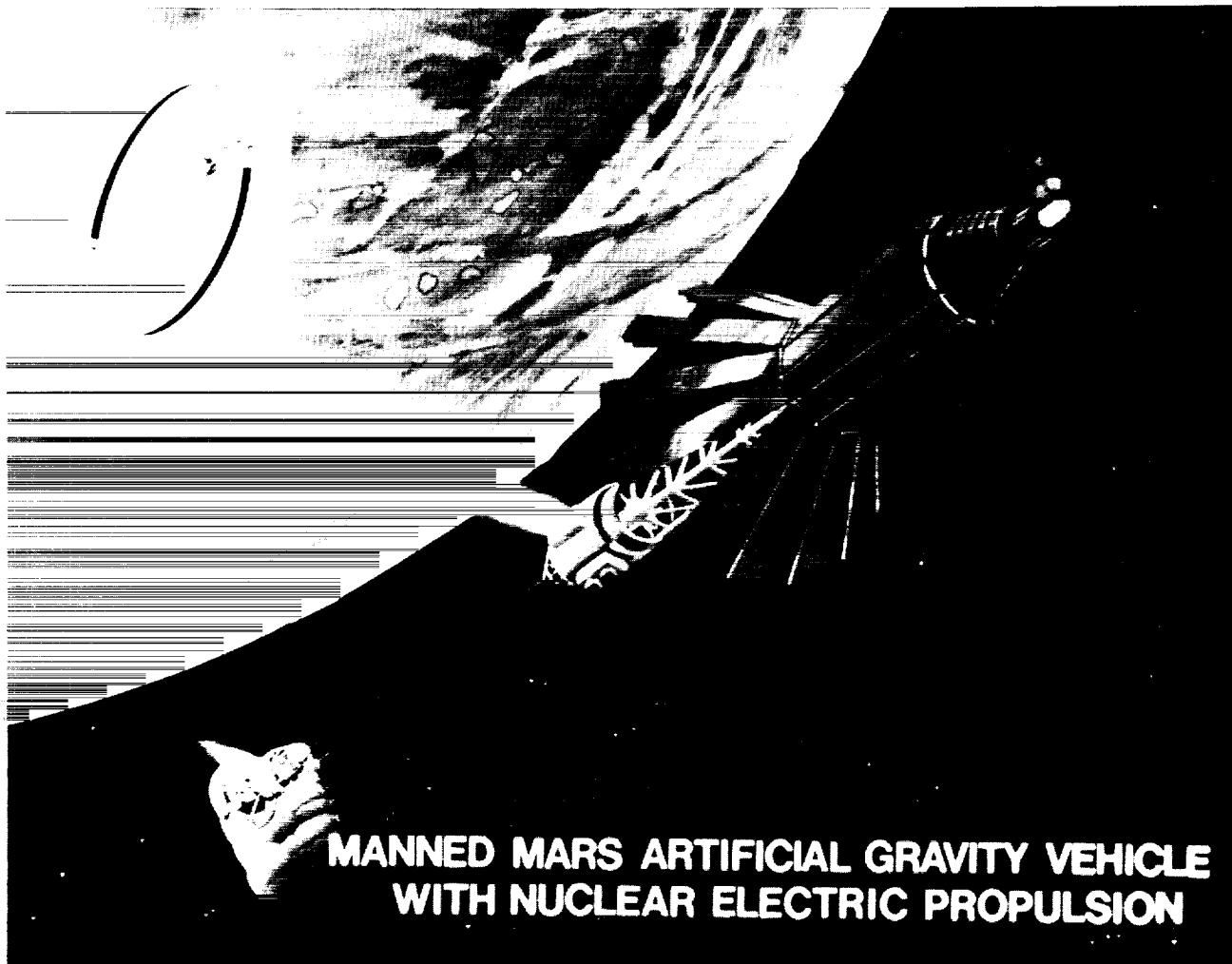




Space Environmental Interactions

Effluents, Neutral and Ionized

- **NEUTRAL EFFLUENTS**
 - Thruster Firings and Gas Dumps
 - Change Vehicle Floating Potential
 - May Interact Chemically with Surfaces
 - May Become Ionized by UV, Critical Ionization Velocity, Charge Exchange
 - Source of Contamination
- **IONIZED EFFLUENTS**
 - Ion Thrusters, Radioactive Sources
 - May Be Attracted Back by E Fields
 - Change Vehicle Potential
 - Increase Local Plasma Density, Arcing, Sputtering, etc.

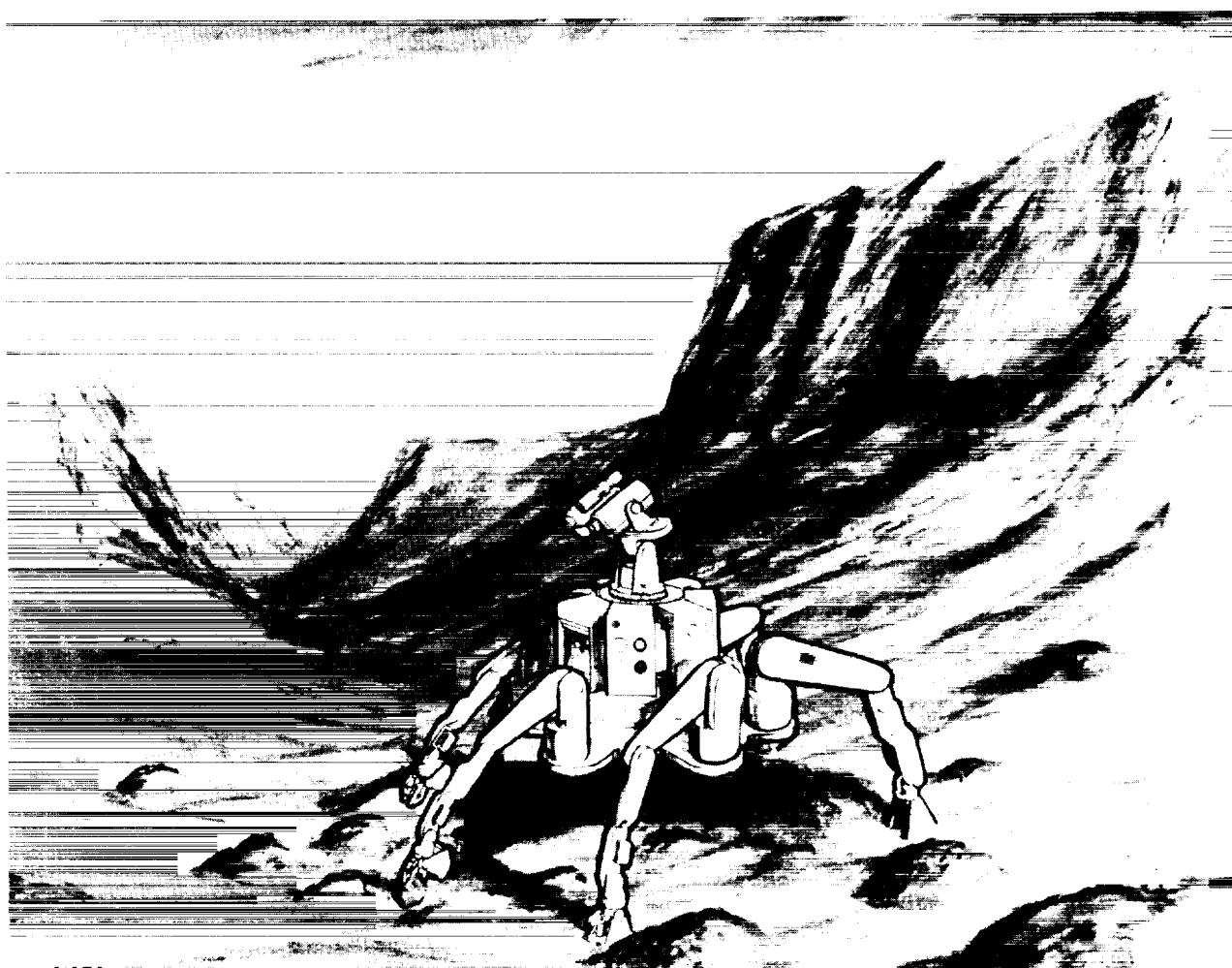


Space Environmental Interactions

Winds, Dust, and Contamination

- **NEUTRAL DUST CONTAMINATION**
 - Propelled by Winds or Rocket Exhausts
 - May Have High Sticking Factors
 - Can Change Thermal, Optical Properties
 - Attracted to Charged Surfaces by Dipole Attractions
- **CHARGED DUST**
 - Mars, Moon - Photoelectric Effect
 - Mars - Triboelectric Charging
 - Attracted Strongly to Charged Surfaces





NASA

